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PROBING THE ATMOSPHERES OF GIANT STARS*

BY ANDREW MCKELLAR

INITIALLY, let me discuss briefly the study by means of the spectrograph, of the atmospheres of ordinary stars. Probably a large number of readers are familiar, at least in a general way, with the operation of an astronomical spectrograph and with the sort of information it enables one to obtain. For those who are not, however, it may be said that the light from a star, when gathered to a point by a telescope, then passed through the optical components of a spectrograph, and photographed, is spread out into a band with the longer wave-lengths at one end and the shorter wave-lengths at the other. In an overall sense, this band, or spectrum, allows the measurement by photometric means of the relative amounts of light of various wave-lengths received from the star, and this enables a quantitative value of the star's colour to be found. Furthermore and of even greater interest, the spectrum shows a structure of lines caused by the absorption of numerous wave-lengths of radiation by the various atomic and molecular constituents of the star's atmosphere. These spectral lines whose counterparts can be studied in the laboratory, are characteristic of the presence and of the physical condition of the atoms and molecules in their source. Therefore, by studying the lines that occur in the spectrum of a star, the chemical composition and the physical state of their source, in this case the stellar atmosphere, can to some extent be deduced.

Ordinarily there are at least two bothersome limitations imposed on the interpretation of such spectrographic investigations. First, we must

*The material in this article was the basis for lectures to the Toronto and the Vancouver Centres, R.A.S.C. in February and November 1953, respectively, and for an Alexander F. Morrison Lecture of the Astronomical Society of the Pacific, California, in January 1954.

accept the integration of the spectrographic effects with depth in the stellar atmosphere. That is, the light in proceeding outward from the interior of the star comes through successively less dense layers of the star's atmosphere, each of which leaves its imprint, and the resulting spectrogram thus shows the results of the sum of the effects of the different layers. To extract the desired information on the physical conditions of the atmosphere, and in particular the variations of these conditions with depth, we must have recourse to theories of the transfer of radiation through models of stellar atmospheres. While the equation of transfer has been solved for various models, the necessity of relying on the theory still remains as a complication between observation and interpretation. A second limitation arises from the fact that even the nearest star (excluding the sun) is so distant that the largest telescopes can show it only as a point of light. Hence, the observed spectrum is dependent not only on integration with depth, but also on the integration of the physical conditions over the whole hemisphere of the star facing toward the observer.

The sun, our own star, is a special case that can be studied with not all the disadvantages described. While the first limitation is still present to a great extent, the second is not. The sun presents to us such a large disk that different sections of the solar surface can be examined spectrographically. For example the variation of the spectrum between the centre and the edge of the sun can be studied, or the image of a large sun-spot can be set on the slit of the spectrograph. In this way it has been shown that the sun-spots correspond to regions at a temperature lower by about 1000° Centigrade than the undisturbed solar surface, and the splittings of lines in spectra of sun-spot areas have long been known to show the presence of magnetic fields associated with spots and have allowed the strengths of these fields to be measured. Indeed very recent developments at the Mount Wilson Observatory have made it possible to scan the solar surface and produce a "magnetic map" at any time. Also at times immediately preceding and following total eclipses of the sun, useful information on the variable structure of the solar atmosphere with distance from the sun's surface can be secured from flash spectra.

The sun is a dwarf star of intermediate temperature (about 6000° Centigrade) and is one of many such objects. There seems no reason, other than its proximity to us, to set the sun apart from other stars of its kind and so it appears safe to conclude that other dwarf stars with spectra similar to that of the sun have atmospheres similar to the sun's. Are there special circumstances that make it possible for us to observe

the atmospheres of any giant stars in particular detail? The answer is "yes". There has come to the attention of astronomers at least one way, provided by nature, for partially overcoming the limitations outlined earlier. The method is applicable as yet to only a very few giant stars—certain double stars having particular properties. It is proposed to describe the particular circumstances, to show how and why the observations are of value and to describe some of the results so far obtained.

Let us consider double stars, their numbers and their properties. Among groups of stars about which we have most complete knowledge, such as those nearest the sun, many are found to be double or multiple stars. By a double or binary star is meant a system of two stars so close together that under the influence of their mutual gravitation, they revolve in elliptical orbits around their common centre of gravity. It is estimated that about one in every three or four stars is a double star.

Those binaries with components far enough apart in angular separation to be seen separately with a telescope are called visual binaries, and have periods of revolution from a few years up to tens, hundreds or thousands of years. Members of a second group, spectroscopic binaries, are double stars too close together to be observed directly as double, but their nature is made apparent by spectrographic observations in which shifts of the spectral lines indicate orbital motion. Often two sets of spectral lines are found, showing that the components are of comparable brightness but more usually one star is so much brighter than its companion that only the one spectrum is seen. The periods of revolution of spectroscopic binaries range from values of the order of a day to tens or hundreds of days and, in a few cases, up to several thousand days. There seems no reason why binaries filling the gap in period between spectroscopic and visual binaries should not exist; undoubtedly they do, but would be very difficult to detect by the means presently at our disposal.

If we restrict our thoughts to spectroscopic binaries, it can next be pointed out that if a large sample be examined, it would be found that their orbital planes would occupy all possible orientations. From our point of view, the particular group of the binaries are those having orbital planes so close to the line of sight from our solar system to the pair, that, in their orbital motion, when the component stars are in the line of sight, the one eclipses the other. That such pairs, called eclipsing binaries, do exist, has been known for many years; their periodic dimming as well as the spectroscopic evidence, gives a clue to their nature and reveals their period of revolution. Indeed the study of eclipsing binaries, of which about three thousand are known, has contributed much of our knowledge of stellar masses and dimensions. Many eclipsing binaries

consist of pairs which are very much alike as regards temperature, size and therefore brightness; these are virtually pairs of "twin" stars. Many other eclipsing binaries have one component so much fainter than the other that they present the phenomenon of a bright star being eclipsed by its unseen dark companion. One very small group of eclipsing binaries, having as yet only four definitely known members, is the group to which I should like particularly to direct your attention. This quartet of binaries remaining after eliminating, first, all non-binaries, secondly, all binaries except spectroscopic binaries, thirdly, all spectroscopic binaries except eclipsing binaries and fourthly, all known eclipsing binaries except the four, are ζ Aurigae, 32 Cygni, 31 Cygni and VV Cephei. These four eclipsing binaries share a particular property, namely, each consists of a very large giant or supergiant cool star and a small hot star and, furthermore, the brightness of the two components is equal somewhere in the ordinary photographic region of wave-lengths (the blue or violet).

For a binary system of the kind described, let us examine first, what is shown by the spectrograph and secondly, what interesting deduction can be made about the physical dimensions of the component stars. The relative distribution of the light emitted from each star would be as shown qualitatively in figure 1. The infra-red, red and yellow light would come predominantly from the cool red star, the blue or violet light would

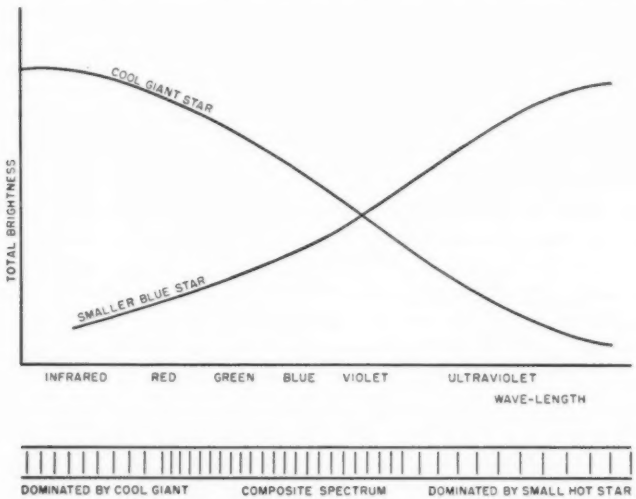

FIG. 1—Schematic diagram of radiations and of combined spectrum.

be approximately equal from each star while in the ultra-violet the light would be mainly from the hot blue star. Therefore, in the spectrum (shown schematically in the lower part of figure 1) where the combined light of the two stars appears as from a single source, the infra-red part of the spectrum would be dominated by the light of the red giant star; the blue-violet part of the light would show the spectra of both hot and cool stars, and would be a so-called "composite spectrum"; in the ultra-violet, the spectrum would be mainly that of the hot star. The way in which the composite spectrum is built up, and its appearance, is shown in figure 2 where the violet parts of the spectra of a cool K-type star and of a hot B-type star are shown separately above and the composite spectrum, where the two are superposed, is shown below. Such composite spectra have a characteristic blurred appearance, recognizable at once to the experienced observer, who then knows that two stars are contributing to the total light.

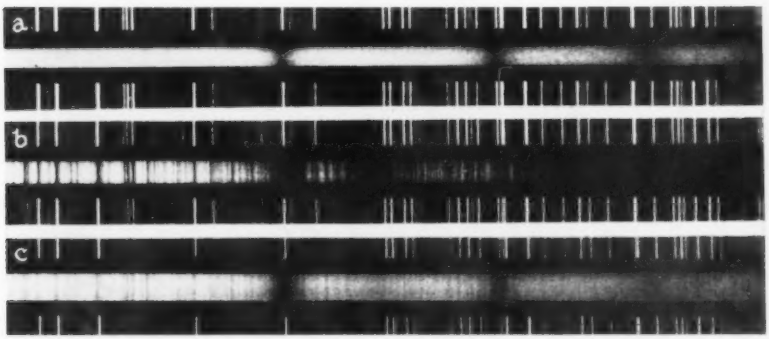

FIG. 2—Illustrating the way in which the composite spectrum is built up. (a) B-type spectrum; (b) K-type spectrum; (c) composite spectrum. Red is to the *left*, violet to the *right*.

What can we say about the dimensions of the two stars? Taking their surface temperatures as about 3,000° and 15,000° K., respectively, making the assumption, approximately true, that the total radiation from each star is equal (that is, that the areas under the curves in figure 1, in energy units, are equal) and applying a basic law of radiation, Stefan's Law, an interesting conclusion is reached. Stefan's Law which gives the total radiant energy from a perfect radiator as σT^4 ergs per square cm. per second, expresses in quantitative terms the well known fact that the energy radiated per unit area increases very rapidly with the tempera-

ture of the source. σ is the well known Stefan's constant and T is the absolute temperature of the radiating surface. Then, for the hemispheres of the two stars facing the observer, each having an area $2\pi R^2$, we can equate the total radiations,

$$2\pi R_c^2 \cdot \sigma \cdot 3000^4 = 2\pi R_H^2 \cdot \sigma \cdot 15000^4$$

where R_c is the radius of the cool star and R_H the radius of the hot star. Cancelling constant factors on both sides, we find that $R_c = 25R_H$. That is, the radius of the cool star must be about twenty-five times as great as that of the hot star. Consequently we can picture such a binary system as shown in figure 3, where the relative sizes of the two stars are approximately to this scale.

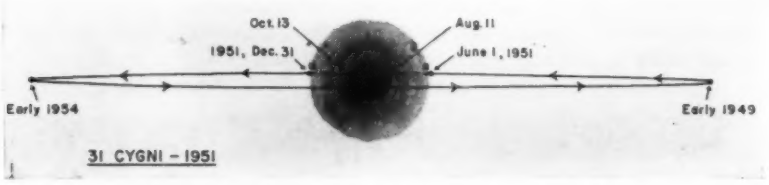

FIG. 3—The binary system, 31 Cygni, drawn to scale.

Let us now consider what a physicist does in the laboratory if he wishes to examine the chemical composition and the physical conditions such as pressure and temperature of a gas or vapour by the means of absorption spectroscopy. He places the gas to be tested in a tube or vessel with windows in it and sets up a bright lamp and lens outside one window in such a way as to send a parallel beam of light through the vessel containing the gas. Then outside the other window he places a second lens that focusses the beam onto the slit of a spectrograph and photographs the spectrum of the light from the lamp. If the vessel were empty, the spectrum of the lamp would be simply an unbroken dark band on the photographic plate. However, when there is in the vessel, gas that can absorb certain wave-lengths of light, a pattern of absorption lines is impressed on the spectrogram. Then, as described at the beginning of this paper, the identification of the spectral lines leads to knowledge of the atoms or molecules present in the gas, and the shapes of the spectral lines are indicative of the temperature and gas pressure.

We see that the eclipsing stars under discussion provide the elements of a laboratory-like experiment similar to that just described. Envisaging the eclipse of the small hot star by the large cool star (see figure 3), we see that the light of the hot star (which shows an almost continuous

spectrum like that of the incandescent lamp) just before and after total eclipse must, on its way to us, traverse the atmosphere of the cool star. In figure 3, such traversal takes place all the time the small star, on the far side of its orbit, is travelling on the part of the orbit shown by a broken line. As total eclipse is approached, the light of the hot star traverses regions deeper and deeper into the atmosphere of the large star and, acting as a light probe, gives us the opportunity to study, spectroscopically, the structure of this atmosphere at varying heights. The detail observable in the structure of the large atmosphere is dependent, among other things, on the smallness of the hot star compared to the atmosphere of the large one (that is, the fineness of the light-probe) and also on the time-scale of the phenomenon.

What does the spectrograph show in the ordinary photographic wave-lengths as the stars proceed in their orbital motions? Each complete orbital revolution may be divided into three phases, spectroscopically speaking. The first and longest occurs when the B star is in front and at the side, in fact at all times except when it is between points *a* and *d* (figure 3) in its orbit. Then the light of both stars reaches the spectrograph and there results the composite spectrum as previously described and as shown in the bottom strip of figure 2. Secondly, when the small hot star is totally eclipsed, that is when it is between the points *b* and *c* (figure 3) in the orbit, we receive only the light from the large star which the spectrograph shows as the spectrum of a late-type giant star, like the middle strip in figure 2. The third and, from our point of view, the most interesting part is that when the small hot star is between *a* and *b* and between *c* and *d* (figure 3) in its orbit. Then, since both stars are sending their light, we photograph the composite spectrum. But in addition, the light of the small star is traversing the atmosphere of the large star, so the atoms of the extended atmosphere leave their imprint by giving additional or stronger absorption lines. Therefore, during this time, the differences between the ordinary composite spectrum and the spectrum observed can be attributed to the effect of the atmosphere of the large star along the path the light travels through it. And, between *a* and *b* as the light travels through successively deeper portions of the large atmosphere, a more complicated chromospheric component of the spectrum is found and, as noted previously, gives valuable clues to the chemical composition and physical state of the extended atmosphere at its different heights. The same spectroscopic phenomena occur in the reverse order following totality, from points *c* to *d* (figure 3). An example of these progressive changes in the violet region of wave-lengths, for the 1951 eclipse of the star 31 Cygni, is shown in figure 4. In these

reproductions of spectra it can be seen that, preceding total eclipse numerous spectral lines appear and strengthen and, that following eclipse, the reverse takes place.

The four binaries known to the present time to be of the kind described are, as mentioned earlier, ζ Aurigae, 32 Cygni, 31 Cygni and VV Cephei. The first three are, on the whole, much alike. They consist of a giant K-type star and a main-sequence fairly late B-type star. For ζ Aurigae and 31 Cygni, the eclipse must be close to central while for 32 Cygni, the B-star passes behind its large companion at a fairly high latitude of the latter. VV Cephei has as its large component a cooler giant star of type M and as its small component, a B-type star. Since the spectrum of the M-type star appears itself to vary irregularly, VV Cephei is in some respects not as satisfactory an object for study as the other three systems. Being, however, the only one involving an M-type star, it is highly important and most worthy of study. Some figures on the eclipses and physical dimensions of the four binaries are given in Table 1.

TABLE I

DATA ON ZETA AURIGAE-LIKE STARS

ECLIPSE DATA

Star	Period	Length of Total Eclipse	Length of Partial Eclipse	Period of Observation of Chromospheric Effects (Before or after Eclipse)	Date of Next Eclipse
	days	days	days	days	
ζ Aurigae	972	38	1.5	10 to 40	Dec. 1955
VV Cephei	7400	450	22	>365	1957
32 Cygni	1141	$\sim$ 12	$\sim$ 3	$\sim$ 40	Jan. 1956
31 Cygni	3802	61	$\sim$ 2	$\sim$ 70	1962

STELLAR DIMENSIONS

Star	Diameter (in terms of solar diameter) of		
	Red Giant Star	Chromosphere of Red Giant Star	Blue Star
ζ Aurigae	$\sim$ 200	$\sim$ 100 to 500	$\sim$ 5
VV Cephei	$\sim$1200	$\sim$3000	$\sim$10
32 Cygni	$\sim$ 200	$>$ 400	$\sim$ 3
31 Cygni	$>$ 150	$\sim$ 500	$\sim$ 5

It is not possible here to give all the historical data and to make reference to all the researches done to date on the four stars. The interesting eclipsing nature of ζ Aurigae was first suspected by Harper in 1924 and made certain by the efforts of the German astronomers Bottlinger, Guthnick and Schneller, and Hopmann from 1926 to 1932. The discoveries of the eclipsing effects of all other three stars were made by D. B. McLaughlin; VV Cephei in 1936, 32 Cygni in 1949 and 31 Cygni in 1950. Researches on the spectra and the light curves of one or more of the four stars have been carried out, in more or less detail, by astronomers from almost every country in the northern hemisphere where astrophysical work is done. Therefore, while reference will be made to various investigations, it must not be thought that those mentioned make up nearly a complete list. ζ Aurigae, both because of its earlier discovery and its shorter period of revolution, has been the most extensively studied system of the four. In the spectroscopic field detailed studies of the chromospheric spectra at several eclipses of this star, have been made. At the present time, the results of Wilson and Abt from Mount Wilson spectrograms of the 1947–48 eclipse, scheduled to be published early in 1954 as one of the first numbers of *Astrophysical Journal Supplements*, are awaited with interest. Rather than discuss ζ Aurigae in any detail, however, it might prove interesting and instructive to describe certain features of the 1951 eclipse of 31 Cygni, the most recent of the four stars to be discovered as an eclipsing binary.

31 Cygni is a star of the fourth magnitude that was found to be a binary by W. W. Campbell at the Lick Observatory in 1901, two years after its spectrum was described as composite at the Harvard College Observatory. Not until 1936 was an approximate spectrographic orbit obtained by W. H. Christie. Subsequently in 1944 Miss Vinter Hansen using the long series of Lick Observations, calculated a more precise orbit and estimated the mass ratio of the two component stars. The period of revolution of the two stars about their common centre of gravity was found to be 3803 days, which is almost 10.5 years. In 1950, D. B. McLaughlin reported that three spectrograms obtained at the University of Michigan Observatory in 1941 showed evidence that the light of the hot star had traversed the atmosphere of the cool star, and so that at least an atmospheric eclipse had taken place. The next time that an eclipse was to be expected was 10.5 years later, in 1951.

Observations of the star were begun at Victoria in May 1951, and all members of the observatory staff took part. On June 2 the first evidence of absorption by ionized calcium atoms in the far outer atmosphere of the large star was detected. Spectrograms of the star were obtained at

frequent intervals throughout June and July; the chromospheric calcium line increased in strength only slowly until the period from July 23 to July 26 when a marked increase in width and intensity occurred. Thereafter the now intense calcium line again strengthened only slowly until August 8, but from then until total eclipse of the small hot star occurred on August 12, the line developed strong wings and grew rapidly in strength. Meanwhile from the end of July numerous chromospheric absorption lines of other elements appeared and grew rapidly in intensity, especially from August 8 to 12. Total eclipse, during which the spectrum observed was only that of the large star, lasted until October 12, and the observations from then until January 1952 showed the same general sequence of phenomena as at ingress (with some minor but important differences to be described later) but in the reverse order. A similar series of spectrographic observations was carried out at the University of Michigan Observatory. The spectrograms of the two observatories give quite a complete record of the 1951 eclipse. In addition to the Victoria and Ann Arbor plates, spectrograms during egress were obtained at the Stockholm and possibly other observatories. The pre-totality growth and post-totality decay of the chromospheric lines can be followed in figure 4.

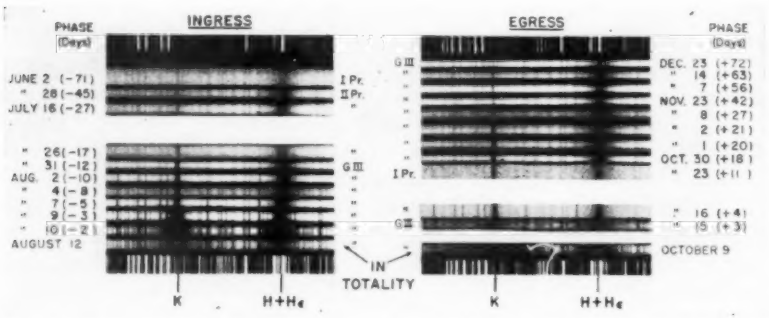

FIG. 4—31 Cygni, 1951. H and K region; corresponding representative phases before and after totality.

Photoelectric observations to determine the light-curve of 31 Cygni at the time of its 1951 eclipse were undertaken at several observatories. Contributions to this aspect of the problem were made by E. F. Carpenter at Tucson, F. B. Wood at Philadelphia, and C. M. Huffer at Madison. While observations at the critical times of ingress and egress were plagued by bad weather at all three places, it was determined that

the total eclipse amounted to 0.12 magnitudes in the yellow, 0.38 magnitudes in the blue, and 1.64 magnitudes in the ultra-violet at λ3650.

As the concluding part of this lecture, some examples will be given of the information obtained so far from study of the four systems under discussion. While the "experimental" conditions remove some limitations usually present, the impression should not be given that all difficulties are swept away. For example, the light from the small hot star still travels through the extensive giant atmosphere along paths of varying density as well as varying distance from the stellar surface (along a chord parallel to a tangent to the stellar surface). Also, it has not yet been possible to define precisely how close the eclipse is to being exactly central for any one of the four binaries, and so an unknown scale factor remains in converting time before and after eclipse to actual kilometres of atmospheric heights.

Stellar and Atmospheric Dimensions—As for other eclipsing binaries, the combination of orbital data with a knowledge of the light curve at time of eclipse provides direct information on the sizes of the two stars. From the radial-velocity curves of the two stars, their relative velocity at time of eclipse is known. This, together with the observed duration of totality allows calculation of the minimum diameter of the eclipsing star. For 31 Cygni, the eclipse lasted 61 days during which the two stars were travelling about 24 miles per second with respect to one another. Thus, assuming that the eclipse is central (which gives a minimum value), the diameter of the large star would be about 125 million miles or almost 150 times the diameter of the sun. The diameter of the smaller B-type star is found from the same relative radial velocity and the duration of partial eclipse, that is, the time between the beginning of the occultation of the small star and its complete disappearance. For 31 Cygni, while the light curve is as yet not well determined, this time interval is known to be about two days which gives a diameter of 4 million miles or 5 times that of the sun for the B-type star.

The extent of the chromosphere of the giant star can be estimated in the same way as the size of the star. From figure 4 it can be seen that the chromospheric absorption lines of ionized calcium were present for more than 70 days before the beginning and 70 days after the end of totality. Therefore the radial extent of the atmosphere beyond the star's surface must be over 175 million miles, that is, the total diameter of giant star plus its chromosphere must be at least 500 times the diameter of the sun. Similarly, considering the times at which the calcium and other chromospheric lines became quite rapidly stronger and finally when they became very strong and winged and many new chromospheric lines

appeared and strengthened rapidly, the picture of the giant star and its atmosphere shown in figure 5 emerges. It is not, of course, suggested that the boundaries between the three atmospheric regions are as sharp as shown nor, probably, as will be seen later, are the regions as uniform and quiescent as pictured; the diagram is meant to illustrate the relative extents of the regions and the comparative size of the B-type star.

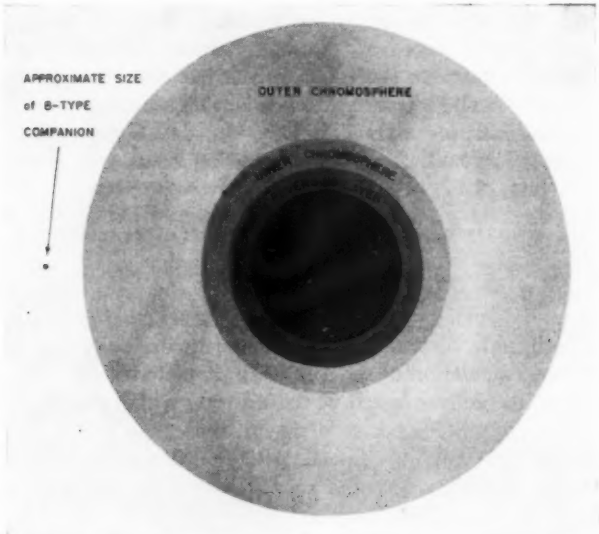

FIG. 5—Relative sizes of atmosphere and disk of K-type component of 31 Cygni (assuming central eclipse).

For ζ Aurigae which has been observed at half a dozen or more eclipses, it has been found that the extent of the chromosphere is different at different eclipses and, sometimes, even between ingress and egress of the same eclipse. Sometimes the chromospheric lines have been visible for only about 10 days, at other times for as long as 40 days. This variability is most probably attributable to prominence-like activity on a large scale, to be referred to later.

Variations in Stellar Atmosphere with Changing Height—As the chromospheric eclipse begins and proceeds, the first two elements detected by their absorption lines are ionized calcium and hydrogen, the former by virtue partly of the observability of its most sensitive spectral lines and the latter, because of its overwhelming abundance. At lower

levels in the atmosphere the lines of ionized metals such as titanium, scandium, chromium, iron, etc. appear, then lines attributable to the neutral metals. All the lines strengthen greatly as the light from the hot star traverses longer and longer paths through the lowest regions of the atmosphere of the large star. By means of "curve-of-growth" methods, too detailed to describe here, the measured relative strengths of the lines at different times can be used to derive values of the density gradients of the atoms of the various elements in the stellar atmosphere, as well as to obtain values for the average turbulent velocities and temperatures at different heights. The work of O. C. Wilson on spectra of ζ Aurigae may be taken as among the most authoritative, and some of his interesting results noted.

The parameter related to width of spectral lines, indicating general state of turbulence of the atmosphere, was found by Wilson to indicate an increase in average turbulent velocity of the atmospheric atoms from 6.5 km./sec. at a height of about one million kilometres to 13 km./sec. at 20 million kilometres. Also, the excitation temperature of the atmosphere was found to increase with height, from about 3500° to 5700° at the above two heights. The rate of change of density with height was found to be about the same for the various elements, and to be steepest at the lower levels, becoming less so at greater heights. These density gradients found were shown to be drastically less steep than would be expected if the atoms were simply held as an atmosphere in gravitational equilibrium as, for example, are those of the earth's atmosphere. For the lightest atom, hydrogen, the density gradient is only one one-thousandth as great and for metallic atoms like iron, about one fiftieth as great as would be expected under conditions of gravitational equilibrium. Therefore some other agencies undoubtedly involving radiation pressures and turbulent motion of the gases, but as yet not understood in detail, must be operative in supporting the extensive atmosphere. It will be interesting to see whether the forthcoming results of Wilson and Abt on the more recent eclipse of ζ Aurigae will give similar results, and also how closely curve-of-growth studies, started at Victoria by K. O. Wright on the chromospheric spectrum of 31 Cygni, will show this star to parallel the behaviour found for ζ Aurigae.

Large-scale Motions in the Extensive Atmospheres—The turbulent motions mentioned in the previous section refer to the motions of atoms or of volumes of material in the lower chromosphere. There is even more direct evidence of large-scale inhomogeneities and motions in the outermost regions of the extended chromosphere of the giant star. W. H. Christie noted that, in the 1937 eclipse of ζ Aurigae, the chromospheric

lines of ionized calcium, after appearing in the spectrum, varied somewhat in intensity over a period of several days. This he interpreted as an indication that clouds of calcium of different densities existed far out in the chromosphere of the giant star. Indeed, even at times quite removed from the dates of eclipse, there occasionally was found a faint calcium line, which could mean that one such cloud reached a distance possibly as far out as the dimensions of the stellar orbits.

Perhaps the most clear and convincing evidence of the existence of discrete moving clouds of matter in the chromospheres of these giant K-type stars, is the occurrence of complex and changing structure in the chromospheric calcium lines in the spectrum of 31 Cygni found during the egress of its 1951 eclipse. During ingress, there was evidence of slight line structure for only a day or two. During egress, however, very definite and changing structure could be seen both on the Victoria and the Ann Arbor plates over a period of several weeks. This is illustrated by figure 6, which shows reproductions of Victoria plates obtained between

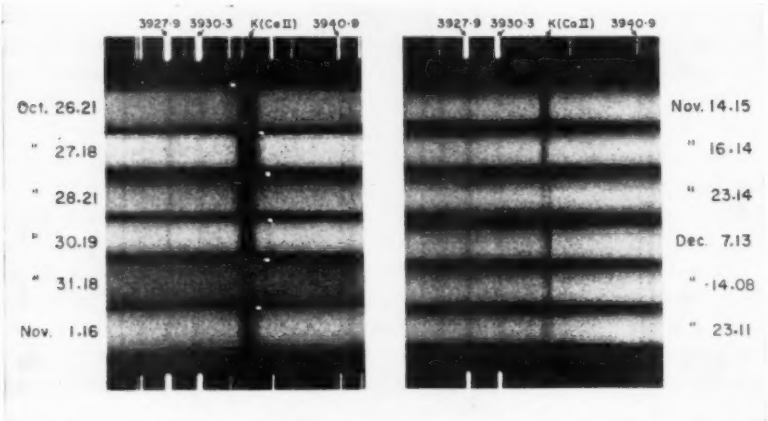

FIG. 6—Spectra of 31 Cygni, 1951, showing varying structure of the chromospheric calcium line during egress.

October 26 and December 23, 1951. Spectra in the left column of the figure were obtained about two weeks after totality, when the chromospheric calcium line was still quite wide. It is seen that this strong line is accompanied by a weak component (indicated by white dots) and that on successive days the weaker component shows different wavelength shifts, to be interpreted as arising from different velocities of the absorbing gas in the line of sight (Doppler shift). The largest shift,

October 30, corresponds to a velocity of 130 km./sec. It cannot be said whether the weaker component for all these days is attributable to the same or different moving clouds of gas. The right-hand column of spectra shows interesting changes in line intensities and line structures during the second month after totality, when the chromospheric calcium lines had become narrower and weaker. The components of the line at this time were separated by amounts corresponding to differences in line-of-sight velocity up to 40 km./sec. The varying intensities of the line-components indicate varying sizes or densities of individual gas clouds.

The most obvious and probably correct interpretation of the line structures is that they are a consequence of motions of large volumes of gas in the chromosphere of the giant star, motions possibly akin to those of solar prominences, but on the larger and lazier scale expected from the size of the giant star and its much lower surface gravity. The irregular nature of the occurrence of the phenomenon is shown by its virtual absence during the ingress compared to its prevalence during egress, for 31 Cygni.

The large-scale picture of the giant atmosphere emerging from our present interpretation of the spectrographic data can be described as a very extensive atmosphere, with a density gradient much steeper at its base than farther out. The lower part may be like a "sea of prominences" to account for the "turbulent velocity" indicated by the intensities of the spectral lines, while the outer chromosphere may contain at any time, one or more large moving masses of gas, possibly the result of a prominence-like activity originating in the lower chromosphere. The structure would thus not be the homogeneous, static one shown in figure 5, which illustrates relative dimensions.

This paper could not have been written if considerable effort had not already been expended at numerous observatories on the four stars under discussion. But, as has often happened in physical science, while yielding much new information of great interest, these observations have also brought to our attention further puzzling problems. Let me, therefore, conclude with the hope that these four interesting stars and any similar ones subsequently discovered be not neglected, but that at each eclipse of each binary, spectroscopic and photometric observations be performed. In this way additional knowledge of the structure of giant atmospheres will surely result, some of which knowledge, so far as I know, cannot yet be secured by any other means.

Dominion Astrophysical Observatory
Victoria, B.C.
December 1953.

PALOMAR EXPLORES THE UNIVERSE

By Ian Halliday

Few scientific ventures have received as widespread publicity and aroused such public interest as the construction of the 200-inch Hale telescope atop Palomar Mountain in southern California. The combination of large and small quantities associated with this telescope has a definite fascination for most people. For instance, the primary mirror is nearly 17 feet across and weighs 15 tons, yet its surface must be accurate to a very few millionths of an inch. The parts of the telescope which must be moved to follow a star weigh 530 tons, but the telescope is balanced so well that this great weight is driven by a one-twelfth horsepower motor, less than one-thousandth of the power of an average automobile engine. The performance of the telescope has been equal to the highest hopes of its makers and the instrument represents a remarkable engineering achievement.

Observations with the world's largest telescope began in 1949 and a great variety of astronomical problems has received the attention of the instrument since then. Conclusions on fundamental problems are usually based on a succession of steps, and each step requires tedious analysis of the observational material, so it is only now that our concepts of the universe are changing as a result of the use of this powerful telescope.

Photographs of the moon and planets have been taken with the 200-inch which are comparable with the best photographs taken with other telescopes. A notable problem relating to our solar system for which the 200-inch has been used was a measure of the apparent diameter of the distant planet Pluto.[1]

In work outside our solar system the Hale telescope has devoted considerable time to detailed studies of individual stars in our Milky Way system, concentrating on the spectra of particularly interesting stars. In this manner information is obtained about the temperature, pressure, magnetic fields, and chemical composition of the stars. Much of this work is closely related to advances in nuclear physics, for the stars offer extremes of temperature and pressure impossible to duplicate in the laboratory, and the behaviour of atoms under these extreme conditions can be inferred from the stellar spectra. In addition to individual stars the 200-inch is examining great clusters of stars; large clouds of dust and gas between the stars; and other constitutents of our stellar system such as planetary nebulae. Most of this work is a continuation of previous studies with smaller telescopes. The 200-inch enables fainter objects to be studied and more detailed information to be obtained.

The primary advantage of a large telescope over a small one is in its larger light-gathering power. For visual observations the magnification used will generally be larger with a larger telescope. The limit is soon set, however, by the unsteadiness of our atmosphere so that there is no point in using very high magnifications. A large light-gathering power will of course enable one to see fainter objects. Almost all modern astronomical observations are made photographically or photoelectrically, and here again the larger light-gathering power permits observation of fainter objects, or of comparatively bright objects in a shorter time, than would be possible with a smaller telescope. Faint objects generally mean distant objects in astronomy so the 200-inch has become the primary tool in the search for information about the remote parts of our universe.

Other Galaxies. The sun is one of about 2×10^{11} (200 billion) stars, which together with clouds of dust and gas make up our Milky Way star system or galaxy. Outside our system there are many others, varying considerably in appearance, and found singly, in pairs, in groups, and in large clusters. They are often called galaxies, or extra-galactic nebulae (indicating they are outside our own galaxy) or quite commonly just nebulae. The last term should not be confused with certain types of objects within our galaxy, such as planetary nebulae which are large clouds of glowing gas surrounding a hot star, or dark nebulae and bright (or emission) nebulae which are even larger clouds of gas between stars which may appear bright or dark.

Only three galaxies other than our own can be seen with the unaided eye. The Large and Small Magellanic Clouds are small companion galaxies of our system and are easily seen from the southern hemisphere. The third one, the Andromeda nebula, is undoubtedly the best known of the impressive spiral nebulae, and can be seen on a good night as a faint hazy patch of light in the constellation Andromeda. Large telescopes reveal great numbers of nebulae in all parts of the sky except where material within our galaxy is dense enough to obscure them. Recent statistical investigations have involved counts of nebulae as high as a few million.

The external galaxies may be broadly classified in three groups: irregular, elliptical, or spiral, as first done by Hubble. The Magellanic Clouds are examples of irregular nebulae, which, as the name implies, have no simple geometric shape. The elliptical systems range from galaxies which are quite spherical to ones which are considerably smaller in one direction than in another. Their shape is a more extreme case of the polar flattening observed for Jupiter. In the case of a highly elliptical galaxy the distance from the centre to any point on its equator would be

several times as large as the distance to one of the poles. The spiral nebulae are also highly flattened objects but are distinguished from the elliptical nebulae by the presence of spiral arms in which the concentration of stars is much greater than between the arms. The arms may be tightly or loosely wound around a central nucleus of stars. In the barred spirals the arms begin at the ends of a central bar. The Andromeda nebula is a large, somewhat tightly wound spiral, and our galaxy is believed to be similar.

Astronomers would like to know many things about these remote systems, such as their distances, sizes, true luminosities, masses, and velocities, as well as their general distribution in space. Of fundamental importance is the establishment of a reliable distance scale for the external galaxies. A concentrated attack on this problem has had top priority on the valuable time of the 200-inch telescope. It seems profitable to consider this problem in some detail.

The Distance Scale. The distances of stars near the sun may be measured directly by trigonometry. As the earth moves around the sun during a year the position of a close star will seem to change slightly relative to the positions of some very distant stars, due to the motion of the earth. The amount of the shift is an indication of the star's distance in terms of the earth's distance from the sun, which is well known. The shift is small for even the closest stars, however, so that only the immediate solar neighbourhood of our galaxy can be charted in this way.

The distances of remote stars are usually found in one of two ways. The inverse square law states that the amount of energy received from a luminous object is inversely proportional to the square of its distance. Thus if two stars are known to emit the same amount of energy and we receive four times as much energy from one as from the other, it is because the fainter star is twice as far away. If the fainter star is three times as distant, we receive only one-ninth as much energy and so on. Now, if we can measure the distance of the close star by trigonometry, we can compute the distance of the other star simply by measuring how much less light we receive from it. Given some knowledge of the true luminosity of an object, then, we can derive its distance by the inverse square law.

The second important method of determining distances involves a statistical treatment of the motions of a group of stars. The stars may be a group of similar stars scattered over the sky or a group of differing types known to be moving together. An example of this latter case is the Ursa Major cluster, discussed recently in this JOURNAL.[2]

For establishing the extra-galactic distance scale the inverse square law is indispensable. In order to apply it, accurate comparisons of the apparent brightnesses of stars are needed. The first stage of the problem, then, involves determining an accurate brightness scale or magnitude scale as it is called. Since very faint objects are involved, the existing scale had to be extended to the faint limit of the 200-inch telescope. The actual comparisons of stars are generally made using a photoelectric cell which gives an electric current proportional to the amount of light falling on the cell. In this manner standard stars have been calibrated and the magnitude scale established.

Photographs of the nearer nebulae taken with large telescopes resolve individual stars in the nebulae. Even the nearest nebulae, however, are so distant that only the brighter stars are resolved. The distance scale depends on recognizing some of these bright stars as being similar to stars in our own galaxy for which we know the distance, and then the application of the inverse square law will yield the distance of the star in the nebula.

Among the bright stars which are easily recognized in the Andromeda nebula are the classical Cepheid variables. These stars go through a regular variation in their brightness, with periods ranging from about one to 100 days. They are of use as distance indicators because of a close relationship between the period of the light variation and their true luminosity. Cepheids with long periods are brighter than Cepheids with short periods. The relationship was first established by Miss Leavitt in 1912 from a study of Cepheids in the Small Magellanic Cloud. Since the entire cloud is at essentially the same distance from us, the apparent brightnesses of the stars indicate the relative absolute brightnesses. To get the true brightness, or absolute magnitude as it is called, the distance of one particular Cepheid within our galaxy would be needed, and then the inverse square law in combination with the period-luminosity curve would give the distance of any Cepheid within our galaxy or in any other galaxy. Cepheids occur in various parts of our galaxy but none is near enough to the sun for a determination of its distance by trigonometry. Statistical methods involving the motions of a number of Cepheids were employed to get a value of their average distance and hence their true luminosity. This was the basis for the extra-galactic distance scale in use before the 200-inch telescope was in operation.

The globular clusters within our galaxy contain among their brighter stars large numbers of variables which are somewhat similar to the classical Cepheids except that their periods of variation are less than one day. These are called cluster variables or short-period Cepheids and

may also be found as individual stars not associated with globular clusters. They are fainter than the classical Cepheids and seemed to represent a continuation of the period-luminosity curve.

The cluster variables are too faint to be seen in the Andromeda nebula with the telescopes in existence before the 200-inch. It was expected that the greater light-gathering power of the 200-inch would record them easily, but when the telescope was turned on the nebula, the cluster variables did not appear. This meant one of two things. Either the classical Cepheids are brighter in absolute magnitude than had been thought and all galaxies are accordingly more remote, since these stars were the distance indicators used, or, the cluster Cepheids are fainter than had been thought. In this latter case all globular clusters within our galaxy would be closer to the sun than previously thought since the cluster variables are the distance indicators used for globular clusters.

The question was settled largely by an examination of colour–magnitude diagrams similar to the one shown in figure 1. The diagram is a plot of the apparent brightness or apparent magnitude, m_{pv}, against the colour, for a large number of stars within the globular cluster Messier 3 in our galaxy.[3] The colour, or colour index, is determined by comparing the amount of light received from the star in two different colours,

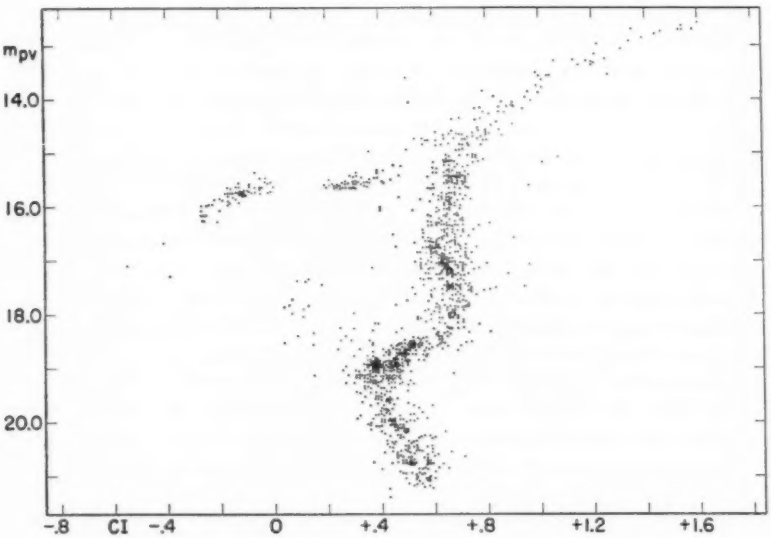

FIG. 1—Colour-magnitude diagram for stars in the globular cluster Messier 3.

say blue and yellow. Stars at the top of the diagram are very bright stars while stars at the bottom are comparable to the sun in brightness. Stars at the extreme right are very red stars while stars at the extreme left are blue. The material for the diagram was obtained from observations with both the 100-inch and 200-inch telescopes.

The diagram shows the brightest stars in the cluster to be red stars (extreme upper right). No variable stars have been plotted, but the cluster variables would all fall in the cluster gap as it is called, which is the break in the horizontal branch of the diagram near $m_{pv} = 15.6$ and $CI = +0.1$. Although the 200-inch does not pick up the cluster variables in Andromeda, it does resolve the bright red stars in the globular clusters of that galaxy. The diagram then shows how bright these stars really are if we can only be sure how bright the cluster variables really are.

The determination of their brightness depends on a study of the motions of similar stars not too remote from the sun. These stars are fainter than the classical Cepheids, they are more plentiful, and on the average the ones we observe are closer, so that their motions appear larger. The calculation of their average distance, and hence their true brightness, should be more reliable than for the very distant classical Cepheids.

The reason the cluster variables are not seen in Andromeda, then, is because our value of the true brightness of the classical Cepheids was too low. The error turns out to be one and a half magnitudes, and is confirmed by recent calibrations of the classical Cepheids themselves. This corresponds to a change in the distance to the Andromeda nebula by a factor of two. The announcement of this fact late in 1952 caused great excitement in the astronomical world. For very distant nebulae the correction will be greater, likely as large as a factor of 2.6, since errors discovered in the old magnitude scale near its faint limit will also increase the distances.

The implications of this startling discovery are many. In addition to placing all external galaxies at much greater distances, all classical Cepheids within our galaxy are twice as remote as previously believed. The period-luminosity curve for Cepheids no longer passes smoothly from the classical to the cluster types. The distance of the globular clusters is unchanged since it depends on the old value for cluster variables which was correct. Since the dimensions of our galaxy are based on a determination of the distances of globular clusters which exist near its boundary, the size of our galaxy is unchanged. All other galaxies, however, become much larger, since increasing their distances increases their true sizes, for their apparent sizes are of course unaltered.

The new values make the Andromeda nebula a shade larger than our galaxy. This is reassuring since astronomers are skeptical of any result which makes our particular surroundings exceptional, and formerly our galaxy seemed the largest of all.

A number of other improvements in relative sizes of objects within and without our galaxy emerge. The diffuse emission nebulae, which are clouds of glowing gas in the Milky Way, no longer seem larger than similar phenomena observed in other galaxies. The same is true for the associations of large, hot, blue stars which can be observed in other spirals. The total brightness of an average globular cluster is now similar in our galaxy and in the Andromeda nebula. Formerly, they appeared fainter in Andromeda, which is now explained by the fact they are more distant than was previously accepted. Of interest to theoretical astrophysicists is the change in our concept of the classical Cepheid stars. They must now be considerably brighter than before, and since their temperature is known from their spectra, they must be much larger in actual size. Their average density is then lower, which is in better agreement with the mathematical theory of the pulsation of these stars which is the explanation of their variable light.

With the distance well determined for a single external galaxy, the Andromeda nebula, the distances of other nebulae become relatively easy to determine. The new distance of Andromeda, or Messier 31 as it is also known because of its number in Messier's Catalogue, turns out to be about 1,500,000 light-years. The 200-inch can photograph individual classical Cepheids to about five times this distance, from which the inverse square law will indicate the distance of any galaxy in which a Cepheid has been observed. Much has been done already with the 200-inch in observing a number of galaxies for Cepheids.

For more distant galaxies a useful indicator of distance is available in novae. These are stars which suddenly flare up to a brilliance equal to about 100,000 suns, and then fade in a few weeks or months to approximately the luminosity they had before the outburst. The rate at which they fade has been found to be an indication of their luminosity, and because of their extreme brilliance, the 200-inch can spot them to about 20 million light-years. Observations on novae are accumulating steadily with a few each year being observed in some large systems.

Our Milky Way is one of about 16 recognized members of the "local group" of galaxies. Other such groups of galaxies are the Virgo Cluster and the Ursa Major Cloud, which are much larger. Observations of Cepheids in the local group and of novae in the other systems should yield a total of about 1,000 nebulae for which accurate distances are known. This should be a sample large enough to include some of all

types of galaxies. Distances of remote galaxies can then be deduced statistically by measuring the total amount of light received from them and comparing with nearby galaxies whose distances are known. This method might not be exact for an individual nebula but should not be very much in error for a group of nebulae. In this manner distances out to the extreme limit of the 200-inch can be derived. This limit is expected to be about 2 billion light-years.

Distances can be derived for large clusters of nebulae with more certainty than for individual systems at tremendous distances. Observations indicate that the very brightest nebula in a large cluster may be somewhat different from the brightest in some other cluster, but that the fourth or fifth brightest members will have very nearly the same luminosity from one cluster to another. Thus a reliable distance can be assigned to any large cluster by comparing the apparent brightness of its fifth brightest member with the fifth brightest member of some nearby cluster, and then using the inverse square law to derive the distance of the remote cluster on the assumption that the two nebulae in question are similar.

The Law of Red Shifts. Once an extra-galactic distance scale has been established, numerous problems are open to attack. The most widely publicized of these is perhaps the law of red shifts. When large telescopes observe the spectra of other galaxies, it is found that the spectra are similar to stellar spectra except that the entire spectrum is shifted toward the red end. The amount of the shift increases very nearly uniformly with the distance of the galaxy observed. The red shift means that the amount of energy we receive each second from an atom in some star in the nebula is less than we would expect for an atom at that distance. This is easily understood if the atom (or star) is moving away from us. Since the star is farther away at the end of a second than it was at the beginning of that second, it will take the light emitted at the end more than one second longer to reach us, because it must traverse a greater distance and started one second later. Thus the energy emitted in one second is spread over slightly more than one second when it eventually arrives at the earth. The result is a change in the colour or quality of the light whereas a mistake in the distance of the nebula would change only the amount of light we receive. This is the argument behind the expanding universe theory, which makes every nebula have a velocity of recession proportional to its distance if the expansion is uniform. Some astronomers do not accept the expanding universe theory but believe the red shift is due to some as yet unknown phenomenon encountered by light in its long trip through space.

With the revised distance scale available, the law of red shifts can be derived more accurately and the 200-inch can extend the observations to much greater distances than were formerly possible. It is important to note that the revision in the distance scale of all galaxies changes the rate of recession with distance accordingly. With all galaxies twice as distant, the time during which the expansion has been going on is also doubled.

Distribution of Nebulae. An important question for which the revised distance scale will be used is a determination of the distribution of nebulae in depth. By counting the number of galaxies between set limits of apparent brightness, the number of galaxies in a given volume of space can be compared for nearby regions and for distant regions near the limit of the 200-inch. These counts will be made using both red and blue light and may show a thinning out of galaxies at great distances.

Density of Matter.—All cosmological theories require some knowledge of the average density of matter in the universe. This implies a knowledge of the masses of typical galaxies. Estimates of the mass of a galaxy may be obtained (1) by observing the speed of rotation of a single nearby galaxy and (2) from the velocities of pairs of galaxies which may move about each other in much the same way as the two components of a double star system.

The density problem brings up the question of the amount of matter which may exist between galaxies. Astronomers are familiar with large clouds of dust and gas between the individual stars of a galaxy. This material is strongly concentrated in the spiral arms of a spiral nebula and shows up as a dark band across the bright background of countless stars when the galaxy happens to be seen edge on. A striking example of this is shown in figure 2 which is a 200-inch photograph of the spiral nebula Messier 104, in the constellation Virgo.

Observations of certain dense clusters of nebulae reveal no galaxies similar to Messier 104, in fact no spiral structure is evident in any member of these clusters. The implication is that the cluster nebulae contain little or no dust. The distance between individual members is only a few times the diameter of any one galaxy, and reasonable assumptions indicate each galaxy must have suffered numerous collisions with other galaxies during its lifetime. The individual *stars* of a galaxy are so far apart that the two galaxies can pass right through each other with perhaps only half a dozen stars coming close enough to stars of the other galaxy to be deflected by gravitational attraction. The particles of dust or gas on the other hand travel a comparatively short distance before they collide, and at very high velocity, with a dust particle from the

FIG. 2—200-inch photograph of the spiral nebula Messier 104 showing dust clouds projected against central nucleus of stars.

other galaxy. The dust will then lose the velocity characteristic of its parent galaxy and the net result will be that all dust will be swept out of both galaxies. Remarkable support for this theory is present in one of the strong sources of astronomical radio energy, known as Cygnus A. It has been identified in position with a peculiar nebula, the brightest of a cluster of nebulae, which is interpreted as two galaxies at present in collision. The spectrum is featured by certain lines of very high energy which would be expected from the collision of dust clouds at high velocity.

The dust swept out of galaxies may have condensed into new galaxies or may be thinly distributed between the members of the cluster. Some support for this latter idea is the apparent scarcity of remote clusters of galaxies when one observes the space between the members of a nearby cluster. The implication is that dust associated with the near cluster obscures the remote clusters which would be expected at great distances behind the near one.

Except for close pairs and groups of galaxies which may have luminous streams of matter between them, and possibly in dense clusters of

galaxies, there is no evidence at present to indicate the existence of large amounts of intergalactic matter. If such evidence should be found, then intergalactic space could not be considered transparent as was assumed in deriving the distance scale. Corrections would have to be applied similar to the ones now in use for the distances of stars known to lie in absorbing matter in the Milky Way. Observations with red and with blue light at great distances might settle the question, as the two colours would be affected by different amounts if appreciable absorption exists between galaxies.

Age of the Universe. The 200-inch telescope may be expected to contribute data which will be used by astronomers and others in discussing an old controversy—the age of the universe. Geologists confidently assign an age of at least three billion years to the earth, deduced from observations of radioactivity in rocks. The revision of the distance scale applied to the law of red shifts and interpreted according to the expanding universe theory implies that the universe has been expanding for about four billion years. It is comforting to have the universe somewhat older than the earth! Some astronomers think the universe is very much older than this value, perhaps 1,000 times as old. The 200-inch may settle the controversy by comparing nebulae at its outer limits with nearby nebulae. Since light from the remote galaxies has spent up to two billion years in transit, we observe them as they were at that time, while we observe nearby systems as they were only a few million years ago. Any systematic difference may mean an evolutionary change in galaxies which could only be compatible with a certain age of the universe.

With these and many more problems before it, there is little likelihood of the Hale telescope running short of work. In general each question opens up a number of previously unconsidered ones, so that the problems to be solved more often multiply than diminish. We may confidently expect many interesting advances as a consequence of operations with this telescope, each one the result of an attempt to enlarge our knowledge of the universe in which we live.

The writer wishes to express his thanks to Dr. I. S. Bowen and Dr. Allan R. Sandage of the Mount Wilson and Palomar Observatories for permission to use the illustrations and for helpful comments on the article before publication.

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VARIABLE STAR NOTES

American Association of Variable Star Observers

By MARGARET W. MAYALL, *Recorder*

Miscellaneous remarks on the variation of some long-period and semi-regular variables during 1953.

000339 V Scl. Needs more observations. Last 3 maxima (in 1952 and 1953) about 10.5, somewhat fainter than normal; the one before that was bright, nearly 9th magnitude.

001620 T Cet. A very good star for binocular observation. It varies from about 5 to 7, with a semi-regular period of 162 days. At times it seems almost constant in light.

001862 S Tuc. A very bright maximum (8¼) in November 1953; previous one was 2 magnitudes fainter, and mean maximum is 9.2.

003179 Y Cep. A good circumpolar variable that needs more observations. Varies from 9.6 to 15.2, with a period of 332 days.

004132 RW And. One of the stars for which more minimum observations were requested in the Sept.–Oct. 1953 number of these notes. Thanks to Messrs. Carpenter, Cragg, and Ford, the December minimum was well covered.

010884 RU Cep. Another circumpolar variable that is excellent for observers with binoculars. It has about one magnitude variation, with maximum at about 8.5.

012502 R Psc. A very bright maximum, brighter than 7, was observed near the end of July. The preceding one in August 1952 was nearly 9th magnitude.

021281 Z Cep. A faint circumpolar variable in need of more observations. It varies from 11.0 to 15.4.

021403 o Cet. The minimum in November was somewhat brighter than normal, about 8.8.

032443 GK Per. This star, Nova Persei 1901, has shown considerable activity recently. In February 1954 it rose from below 13 to about 12th magnitude in 10 days.

044349 R Pic. The light curve of this semi-regular variable was reproduced in the July-August 1953 number of these notes. The star was brighter than 8th magnitude for the 250 days following the published curve.

050001 W Ori. A good star for binoculars. It is quite red (spectrum N) and varies between 6th and 7th magnitudes.

054319 SU Tau. After 10 years of inactivity, this R Coronae Borealis-type star has at last started to decrease. In the latter part of February 1954, several members reported that it was going down. In 15 days it has dropped more than 2 magnitudes. The last minimum of SU Tauri was in February 1944, when it went from 9.5 to 13.5 in about 40 days. At that time it did not get back to maximum brightness for more than one year.

054615c RU Tau. More observations are needed of this star. They should be made with extreme care, for there has been too much scatter (at times as much as 3 magni-

tudes!) of observations, perhaps due to inconsistent comparison stars. The star varies from 10.5 to 14 with a period of more than 550 days.

065208 X Mon. This star became too irregular to predict dates of maxima and minima. For several years it varied between 7.5 and 9, with a period of 155 days, but early in 1952 the range decreased to less than one magnitude, with no well-observed maxima or minima. About Nov. 1, 1953, there was a maximum of magnitude 7.5, followed by a 9th magnitude minimum the last of January 1954. It may be resuming its regular variation this year.

070109 V CMi. Bright maximum (7.8) observed early in November.

073508 U CMi. More observations needed. A wide still-stand on the rising branch of the light curve extends almost to the predicted minimum.

082476 R Cha. A bright maximum, 8.0 on Sept. 14, 1953, followed a faint one, 9.7, on Oct. 14, 1952.

093178 Y Dra. Another circumpolar variable that is being neglected. Its mean light curve shows variation from 9.1 to 14.3, with a period of 326 days. It was too poorly observed in the fall of 1953 to determine the time of maximum, but the previous maximum was a faint one, 10.2, about Jan. 20, 1953.

103270 RZ Car. A faint maximum, 11th magnitude, in the middle of February 1953, was followed by a bright one, about 9.2, early in November.

131546 V CVn. A good variable for binoculars. It varies between 7th and 8th magnitudes, period 194 days.

140113 Z Boo. More observations needed of this star.

140512 Z Vir. Another variable that has been neglected. Observations needed throughout the period.

142539 V Boo. A minimum observed early in September, about 10.5, was the faintest it has been since 1949.

150605 Y Lib. More observations needed. No maximum has been observed since March 1952. The star varies from about 9 to 14, period 275 days.

151731 S CrB. A faint maximum (about 8.2) was observed in July. The preceding one in June 1952 was about 7th magnitude.

152714 RU Lib. The maximum in July was 7.2, about one magnitude brighter than normal. The preceding one in September 1952 was faint, about 8.8 magnitude.

153020 X Lib. Very few observations have been received of this star. More are needed in order to predict times of future maxima and minima.

153215 W Lib. Another star for which observations are needed.

162816 S Oph. The heights of maxima of this star vary from about 9 to 11. The maximum observed the first of June was magnitude 10.6, the 2 preceding ones in 1952 were between 9 and 9.5, and a very well observed one the first of July 1951 was 11th magnitude.

175458a T Dra. The greatest care must be taken in observing this variable, because of a close companion. UY Dra is constant in light, 10.7 magnitude, and precedes T by 1.4 seconds, south 0.2 minutes of arc. Estimates should not be attempted of T Draconis unless the companion can be separated.

192150 CH Cyg. A good variable for binocular observations. It varies between 7th and 8th magnitude, semi-regular, period about 100 days.

192745 AF Cyg. Another interesting semi-regular variable for binocular observations.

200715a S Aql. Irregularities in the light curve of this star have been very striking.

At times what appears to be a secondary wave forms another maximum near the predicted time of minimum light.

201008 R Del. A faint maximum, about 9.6, was observed the last of August. The preceding maximum was brighter than 8th magnitude.

204*2*15 U Cap. More observations needed of this variable.

204318 V Del. Careful observations are needed of this star, particularly around time of minimum and on the rising branch of the light curve. The observations received have been very discordant.

204954 S Ind. A very bright maximum, about 7.5, was observed in July. The preceding maximum was about 10th magnitude.

212*8*14 Y Cap. More observations needed of this star. Times of maxima and minima are impossible to predict from the few observations received.

213244 W Cyg. An excellent variable for binocular observations.

222129 RV Peg. A faint, broad maximum was observed in August, below 11th magnitude. The preceding maximum was about 9.5 in June 1952.

225342 TV And. Like so many of the red variables with periods near 100 days, TV And becomes very irregular at times. During 1953 the range decreased to about one magnitude, and times of maxima and minima were nearly reversed from the predicted times.

231539 RY And. More observations needed.

Notice of Spring Meeting: We are proud to announce that Columbia University in New York, now holding its Bicentennial Celebration, has invited the A.A.V.S.O. to hold its Spring Meeting there on Friday and Saturday, May 7–8. It is a great honour to participate in the celebration of their 200th year, and we are looking forward to an extremely good meeting.

Nova Search Programme: During the months of February and March 1954, reports were received from the following six observers. Listed for each observer is the month the observations were received, the areas observed (in italics), the number of nights the region was checked, and finally, the limiting magnitude.

ADAMS, ROBERT M., Feb.–*1*, 2, *16*, *17*: 2, 8;
Mar.–*1*, 2, *11*, *12*: 2, 8.

DARSENIUS, GUNNAR, Feb.–*Dome*: 3, 2; *16*, *17*: 5, 6;
Mar.–*16*, *17*: 1, 6.

DIEDRICH, DELORNE, Feb.–*94*: 1, 4;
Mar.–*Dome*: 1, 2; *94*: 5, 6; *94*: 2, 5.

DIEDRICH, GEORGE, Feb.–*Dome*: 4, 2; *56*: 4, 6;
Mar.–*Dome*: 7, 2; *56*: 9, 6.

RICK, LOUIS, Feb.–*Dome*: 1, 2; *18*, *65*: 1, 5; *18*, *65*: 2, 4;
Mar.–*Dome*: 6, 2; *Dome*: 1, 1; *18*: 6, 5; *18*, *65*: 1, 4; *65*: 5, 5.

ROSEBRUGH, DAVID W., Feb.–*Dome*: 4, 3; *1*, *34*: 5, 4;
Mar.–*Dome*: 8, 3; *1*, *34*: 7, 4.

Observations received during February and March, 1954: During February 50 observers contributed 4,103 observations, and in March we received 3,349 from 51 observers, a total of 7,452 for the two months.

Observer	February No. Var.	February No. Ests.	March No. Var.	March No. Ests.
Abbey, Leonard B.	6	15	17	49
Adams, Robert M.	64	151	63	156
Alexander, Jack	...	...	1	1
Alvarez, Hector	6	6	5	5
Anderson, Curtis E.	28	56	101	200
Aronowitz, Charles	66	241	73	277
Barber, Walter F.	...	...	2	7
Beidler, Herbert B.	15	15	26	44
Botham, John H.	13	30	...	...
Boutell, Hugh G.	2	3	6	8
Buckstaff, Ralph N.	2	2	4	4
Burden, Jane	...	...	1	1
Calamaras, Helene	...	...	3	4
Carpenter, Claude B.	72	80	127	156
Chandra, Radha G.	70	91	78	106
Chester, Bryant	9	9	10	10
Cragg, Thomas A.	98	108	213	250
Cuevas, Charles	...	...	1	1
Darsenius, Gunnar	32	237	19	75
Diedrich, DeLorne	1	1	2	5
Diedrich, George	2	4	5	10
Elias, Demetrius P.	96	608	...	...
Erpenstein, Oscar M.	...	...	4	4
Estremadoyro, V. A.	4	5	...	...
Fernald, Cyrus F.	31	31	32	52
Ficonetti, Rene	11	13	...	...
Ford, Clinton B.	81	89	108	119
Gaustad, John	4	4	20	31
Goodsell, J. G.	5	5	2	2
Greenley, Robert M.	16	21	20	20
Hartmann, Ferdinand	130	143	124	130
Howarth, Mark	14	14	...	...
Johnsson, Robert G.	...	...	2	2
Kastin, Harold	24	49	38	143
Kelly, Frank J.	12	22	10	12
Knowles, Jeremy	7	23	...	...
de Kock, Reginald P.	108	449	100	439
Kuenzi, Edward W.	11	16	...	...
Lizotte, Eugene A.	...	...	25	62
Lonak, Eugene	4	20	4	14
Maran, Stephen	46	92	48	100
Mebius, William G.	...	...	3	7
Miller, William A.	10	11	10	11
Montague, Allen C.	18	25	24	25
Oravec, Edward G.	104	223	112	275
O'Sullivan, William H.	9	14	15	24
Overbeek, Michiel D.	80	248	...	...
Owen, Toby	...	...	12	23
Paulton, Edgar M.	...	...	1	1
Pearcy, Robert E.	5	5	5	5
Peltier, Leslie C.	45	140	32	116
Renner, C. J.	185	193	...	...
Rick, Louis	1	1	1	2
Rizzo, Patrick V.	56	100	57	97
Rosebrugh, David W.	16	57	15	90
Royer, Ronald	5	19	13	39
Taboada, Domingo	135	214	77	82
Thomas, Morgan A.	7	9	7	16
Venter, S. C.	60	137	...	...
Wyckoff, Jerome	31	41	22	30
Zimmerman, W. W.	13	13	7	7

A.A.V.S.O. Headquarters
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March 1954

REVIEW OF PUBLICATIONS

Amateur Telescope Making (Book Three) edited by Albert G. Ingalls. Pages viii plus 644; 6½ × 7½ in. New York, Scientific American, Inc., 1953. Price $7.00 U.S., $7.35 foreign.

This is a new *addition*, not a new *edition*, in the well-known A.T.M. series. It bears a strong family resemblance to its older brothers in binding, paper stock, and format but the attractive illustrations of Russell W. Porter, to whom the book is dedicated, will be missed. The editor's zephyrous style pervades the text as he first-names the contributors and interjects his comments here and there like a master of ceremonies.

There are forty-odd articles arranged more or less alphabetically by author. The book is so packed with information that the brief index is of little use. Seven of the articles are about the Schmidt camera, a subject treated only briefly in A.T.M. Advanced. The T.N. (the reviewer understands this to mean "Telescope Nut") who wants to aluminize his mirror will find a thirty-page article on high vacuum equipment. For the T.N. who is also an E.N. there are directions on how to assemble electronic equipment for a stellar photoelectric photometer. In fact considerable emphasis is placed on auxiliary equipment which can be built by the amateur for his telescope—eyepieces of course, but also monochrometers (for solar prominences) and optical correctors (for converting a paraboloidal mirror into a wide-field photographic telescope), to name only a few. Other articles range from thermal effects of observatory paints to a layman's account of the phenomenon of the interference of light.

The book was "written for all those who are interested in optics, though essentially for amateurs". It is in the nature of a symposium in that it brings together professional astronomers, experts in the optical trade, and dedicated amateurs each to discuss his own field with authority and enthusiasm. It should have a wide appeal.

D. A. MacRae

General Catalogue of Stellar Radial Velocities by Ralph Elmer Wilson. Pages x plus 344; 8½ × 11in. Washington, The Carnegie Institute of Washington, Publication 601, 1953. Price $2.50 paper, $2.85 cloth.

It is 85 years since the English astronomer, Sir William Huggins, made the first estimates of the radial velocities, that is to say, motions in the

line of sight, of a few of the brighter stars. Huggins, using a laboratory spectroscope fitted to a small telescope, tried to detect and estimate the amounts by which the hydrogen absorption lines in the stellar spectrum were displaced from the bright hydrogen lines which he formed alongside from a discharge tube. From his eye estimates of the displacements he ventured to list the stars which were approaching and those which were receding. Poor as the first measures were, they heralded a powerful new method of studying stellar motions which was destined to discover new double stars by the hundreds, to throw new light on the mechanism of variable stars and to yield up the secret of galactic rotation.

Observatories in the Americas, Europe and Africa devoted much of their time to the fertile new field, and, by 1932, when the first comprehensive catalogue of radial velocities was published by Dr. Joseph H. Moore of the Lick Observatory, 6739 stars had been investigated in this way. Hardly had this catalogue been published than it became apparent that a new one would soon be needed, and by 1951 Dr. Ralph E. Wilson of the Mount Wilson and Palomar Observatories had collected radial-velocity data on more than as many stars again from those observatories still working in this field. Now all the new data, as well as the old, have been collected together in a new catalogue which lists 15,106 stars with their positions, magnitudes, proper motions (where known) and radial velocities. Other galactic objects such as clusters and nebulae are included. These data assembled in this way will be of inestimable value to anyone making any systematic study of stellar motions, and the astronomical world owes a great debt to the perseverance of Dr. Wilson.

It is a pleasure to be able to report the significant contributions made by Canadian Observatories to the radial-velocity observations listed in the new catalogue. Ottawa, in the early days before the 15-inch telescope was outstripped by the large reflectors, had observed 181 stars; Victoria, since 1918, has observed nearly 3300, or 22 per cent. of the total; and Dunlap, since 1935, has observed nearly 1800, or 12 per cent. of the total. Dr. Wilson states in his foreword that only five observatories are now continuing this line of work, and, of these, but two are presently engaged in extensive programmes. He must be referring here to Victoria and Dunlap. Victoria is working on a velocity programme embracing 800 O- and B-type stars brighter than magnitude 9.5 north of declination $+10°$, and Dunlap now has ready for publication velocities of more than 800 late-type stars not included in the new catalogue.

It is true that the field of radial-velocity measurement no longer has the vogue it once had, but it would be more than rash to state that the need for new data has passed. Indeed, even since the new General

Catalogue went to press, a new need has become apparent, namely for the velocities for the stars in the stellar associations, groups which are so young that they must be regarded as the very birthplaces of the stars.

J. F. H.

Der Sternenhimmel, 1954. Pages 118; 5¾ × 8¼ in. Aarau, Switzerland. H. R. Sauerlander and Co. (Obtainable through Mr. Albert J. Phiebig, 545 Fifth Ave., New York 17, N.Y.)

This fine little year-book is published annually under the auspices of the Swiss Astronomical Society. Of particular interest to the amateur are the excellent photographs, drawings and maps.

W. R. H.

Astronomical Photoelectric Photometry edited by Frank Bradshaw Wood. Pages vii plus 141; 6¼ × 9¼ in. Washington, American Association for the Advancement of Science, 1953. Price $3.75.

During the last ten years the development of extremely light-sensitive photomultiplier tubes has made it possible to measure the colours and magnitudes of both bright and faint stars with an accuracy far surpassing that attained using photographic plates. One of the biggest difficulties in using these photomultiplier tubes is the necessity of having an extremely good electronic instrument to amplify and record the current from such tubes. So far three types of amplifiers have been employed which use direct-current, alternating-current, and pulse-counting techniques. The purpose of this little book is to describe to the reader the properties of each type of instrument, and in particular to indicate which instrument is best for any specific type of problem.

Each chapter has been written by an author who has built and operated the instruments which he describes. The reader therefore is given a first hand account of difficulties encountered and methods of overcoming them. Of particular value is a very extensive bibliography which includes not only references to the technical electronic problems but also references to astronomical papers which are based on measurements made with photoelectric photometers. It is perhaps unfortunate that a considerable portion of the book is devoted to pulse-counting techniques which are still used only in a few observatories. In spite of this, the book should provide very valuable information for anyone interested in, or desiring to build, an astronomical photoelectric photometer.

J. B. O.

Tables of 10^x, National Bureau of Standards Applied Mathematics Series 27. Pages viii plus 543; 8 × 10½ in. Government Printing Office, Washington 25, D.C., 1953. Price $3.50.

Although a number of handy tables of logarithms to ten or more places are available, it has until now been necessary to use inconvenient inverse interpolation for finding antilogarithms. This new table of 10-place antilogarithms remedies this. The first table of this volume gives 10^x to 10 significant figures for values of x between 0 and 1.00000 in steps of 0.00001. A basic radix table is also included when 15-figure accuracy is required.

J. B. O.

A Bibliography on Meteorites, edited by Harrison Brown. Pages viii plus 686; 6 × 9 in. Chicago, The University of Chicago Press, 1953. Price $10.00.

So great has the volume of scientific literature become in our day that a researcher must be an expert indeed to know the literature of his own subject as thoroughly as he needs to know it. In a field other than his own he may feel utterly at sea. This is why bibliographies are assuming increasing importance.

Of particular value is the present *Bibliography on Meteorites* because of the hybrid nature of this subject, touching as it does on astronomy, atmospheric physics, geology and chemistry. The editor is Professor Harrison Brown of the Department of Geochemistry at the California Institute of Technology, an acknowledged authority on meteorites. This volume, it is stated in the introduction, will be followed soon by a two-volume set outlining our present knowledge concerning meteorites and including lists and indexes of meteorites, tables of chemical analyses and the like.

As to the present volume, it is strictly a bibliography with an appended index of authors. An attempt has been made to include all references to meteorites and related topics published between 1491 and 1950. The first reference is to the well known passage in Plutarch's Life of Lysander (Latin edition, 1491) in which he speaks of a stone which, "according to common opinion, fell from heaven". There are references to some 9000 original articles all told, each listed by date and author, with title, location of the article and location of any known abstract, condensation or translation. Some of the listings refer to newspaper articles, but mostly they refer to scientific journals. Those written in Russian, of which there are many, include the original titles and English translations of the titles.

The material of the *Bibliography* is well adapted for the investigator

who knows dates or authors, but there is no index by topic. Thus, if I know that Millman has written on meteor spectra since 1937, I can find references to all his writings on this topic very quickly, since the authors are listed alphabetically in each year. On the other hand, if I want all references to meteor spectra, I must read every title, starting with the earliest likely date. However, the promised third volume of the trilogy will contain an index of topics. If this will refer to the items in the present volume, then the value of the latter will be tremendously increased.

J. F. H.

Measurements of Double Stars by G. van Biesbroeck, Publications of the Yerkes Observatory, vol. 8, part 6. Chicago. University of Chicago Press, 1954. Price $10.00.

In the field of visual binaries the emphasis in recent years has shifted from surveys to accurate observations of position angle and separation. Methods of determining stellar masses are all too hard to come by, but in the case of a visual binary, when the observations are sufficient to determine the orbit, the dynamical elements, a and P, lead to the mass of the system if the parallax is known; otherwise the dynamical parallax can be obtained. Although pairs with angular distances of 2″ or more can now be measured quite accurately by photography, the observation of *close* visual binaries remains the burden of the visual observer. Moreover slow-moving well-separated pairs often become fast-moving close binaries when they close in to periastron, and observations at such times are critical.

One of the principal programmes of the 82-inch reflector of the McDonald Observatory in Texas has been the measurement of close orbital pairs by Dr. G. van Biesbroeck using the Yerkes visual micrometer. Dr. van Biesbroeck was the pioneer in the use of a large reflector for this purpose. The results of eight years of observing (1943–1951) have recently been published in vol. 8, part 6, of the *Publications of the Yerkes Observatory*. The catalogue contains something like 2200 double stars, most of them with separations between 0.″10 and 1.″0, for which over 10,000 individual measurements are recorded. New or revised elements for 19 close systems are also given, and dynamical parallaxes for many more.

About half of these observations were made after Dr. van Biesbroeck reached the emeritus age. This volume well illustrates why its author enjoys the reputation he does for outstandingly keen eyesight and devotion to observational astronomy.

D. A. MacRae

NOTES FROM OBSERVATORIES

David Dunlap Observatory

Preparations are being made to observe the total solar eclipse at Mattice, Ontario. A polar axis and a grating spectrograph have been constructed in the Observatory workshop, and other eclipse apparatus built for previous eclipses has been put in readiness. Photographic observations of the flash spectrum and of the corona are planned. A party of three will be at Mattice for about three weeks to set up the equipment, and a further party of three will be at the site for a few days before the event to drill for the operation of the instruments during the 90 seconds of totality.

Observations on an extended programme for the radial velocity and the spectral classification of 1050 stars have now been completed. In order to supplement the data now available for these stars, a programme has been instituted for the accurate determination of their apparent magnitudes. A co-operative arrangement has been worked out whereby photographs will be obtained with the Schmidt telescope of the Hamburg Observatory and measured with the astrophotometer at the Warner and Swasey Observatory. The photoelectric data will be obtained with the 19-inch telescope here.

Concern is being felt by the University authorities over the urbanization of the areas adjacent to the Observatory. If this proceeds without some measure of control of light and smoke there is danger that serious limitation of observational programmes may ensue. This fate has already overtaken many other observatories, in some cases eventually necessitating removal of the larger instruments to more remote sites.

Dr. Adriaan Blaauw, formerly of Leiden Observatory, now of the Yerkes Observatory, was a visitor here during the week of April 5th. He lectured to the Toronto Centre of the Society on the subject of "The Birthplaces of the Stars", and gave a colloquium on "The Young Stars and the Places of Their Formation". Members of the Observatory staff had the opportunity to consult with him regarding radial-velocity determinations and stellar associations.

METEOR NEWS

By Peter M. Millman, *Dominion Observatory, Ottawa*

Observations of the Perseid Shower, 1953

Several active groups have reported observations made during August of 1953. As in past years the Montreal Centre of the Society carried out visual plotting and recording of the Perseid meteors. The Regina Astronomical Society recorded visual rates and magnitudes and also made some exposures with both direct and spectrographic cameras. The various groups observing have been numbered for ease in reference.

1. *Montreal, Que.* (lat. 45° 28′ N., long. 73° 38′ W.)

Observations were carried out on the grounds of Lower Canada College for six hours on the night of Aug. 11/12. All meteors were timed and plotted. The sky was clear but considerable interference was experienced due to a bright auroral display which was present during most of the observing period. The program was organized by Miss I. K. Williamson. Those taking part are listed below:

E. E. Bridgen, F. DeKinder, D. Garneau, C. M. Good, B. Jones, T. Noseworthy, Miss Rosemary Rice, R. Venor, Miss I. K. Williamson, Mrs. J. Wright, K. Zorgo.

2. *Hemmingford, Que.* (lat. 45° 03′ N., long. 73° 35′ W.)

Meteors were recorded but not plotted during four nights by Mr. A. R. MacLennan, member of the Montreal Centre, assisted by Mrs. A. R. MacLennan and Mr. D. E. MacDonald. An overcast sky made observations impossible on Aug. 14/15.

3. *Regina, Sask.* (lat. 50° 27′ N., long. 104° 37′ W.)

A large observing party from the Regina Astronomical Society timed and made magnitude estimates of all meteors visually observed on three nights over a period of four hours each night. This work was carried out on the grounds of Regina College. Weather was generally clear but, as in Quebec, the aurora caused considerable interference during the first night of observation. The programme was in charge of Mr. J. V. Hodges. The observers were organized in two complete teams of ten members each. These teams relieved each other at intervals, thus making possible a continuous watch of the entire sky. A list of all those taking part is given below:

Tom Apperley, Bill Armstrong, Mrs. Jo Dunn, Earl Hanes, Mrs. Sybil Hanes, Berne Haysom, Mrs. Elsie Haysom, J. V. Hodges, Mrs. Jean Hodges, J. C. Hodges, Miss Fay Hodges, Gerald Hodges, Al Irwin, W. P. C. Kinsman, I. Lipton, Miss Enid

Lumsden, T. R. McFarne, Jack McNiel, Allan McRuer, G. Stewart, Joe Thauberger, Johan Toews, Mrs. D. Wettlaufer, Gordon White, Mrs. J. Worel, Milow Worel.

Mr. J. G. McNeely used two cameras, a direct instrument with F/4.5 lens of 101 mm. focal length, and a spectrograph with a 30° prism, F/4.5 lens, focal length 105 mm. Four exposures were made on Aug. 12/13 for a total exposure time of 2.6 hours with the direct camera. Five exposures were made with each camera on Aug. 13/14 for a total exposure time of 2.8 hours with the direct camera and an equal total exposure time with the spectrograph. Unfortunately no meteor photographs were secured.

4. *Westview, B.C.* (lat. 49° 50′ N., long. 124° 32′ W.)

Mr. Glenn Hardie carried out observations at this point on three nights. He plotted and timed all meteors seen. Weather was generally clear.

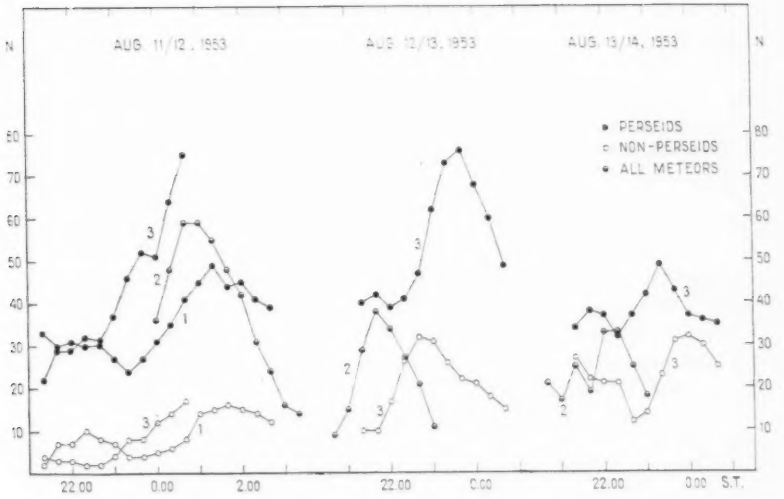
A summary of the total numbers of meteors observed is given in Table I. Observing periods are E.S.T. for Stations 1 and 2, M.S.T. for Station

TABLE I

SUMMARY OF PERSEID OBSERVATIONS, 1953

Station	Date (1953)	Observing Period (Standard Time)	Average Number of Observers	Total Meteors Observed	Average Rate per Hour
1. Montreal	Aug. 11/12	2100–0300	4	226	38
2. Hemmingford	Aug. 11/12	2320–0400	2	77	17
	12/13	2020–2315	2	34	12
	13/14	2020–2315	2	35	12
	15/16	2110–2130	2	2	6
3. Regina	Aug. 11/12	2100–0100	10	253	64
	12/13	2100–0100	10	355	89
	13/14	2100–0100	10	293	74
4. Westview	Aug. 12/13	2130–2230	1	30	30
	13/14	2100–2230	1	15	10
	14/15	2115–2215	1	7	7
			Grand Total	1327	

3, and P.S.T. for Station 4. When allowance is made for the bright aurora on Aug. 11/12 it may be concluded that the total meteor rate dropped steadily from Aug. 11/12 to Aug. 15/16. This would indicate that the Perseid maximum occurred on the morning of Aug. 12 in 1953. This agrees with the tentative conclusions from the visual observations made at the Dominion Observatory. Rates reduced to a standard of six ob-



Hourly meteor rates, reduced to a standard of six observers, plotted against Standard Time. The numbers in the figure correspond to those assigned the observing stations.

servers are plotted in the figure. The higher Regina rates as compared with those from Montreal are probably a result of the fact that meteors were not plotted at Regina.

TABLE II

MAGNITUDE DISTRIBUTIONS

Station and Meteor Type	−4	−3	−2	−1	0	1	2	3	4	5	6	Totals	Mean Mag.
Aug. 11/12													
1. (P)	2		2	5	8	29	57	46	22			177	2.06
3. (P)					4	33	54	71	51	5		218	2.67
2. (P + N)			1	1		10	12	17	35	1		77	2.95
1. (N)				2	3	6	14	13	5			43	2.16
3. (N)						1	4	11	17	2		35	3.43
Aug. 12/13–15/16													
3. (P)				2	3	21	77	157	117	61	3	441	3.25
4. (P)					5	3	3	9	9	5		34	2.82
2. (P + N)			1			7	13	13	28	8	1	71	3.23
3. (N)				1		3	17	80	73	33		207	3.54
4. (N)						1	5	5	4	2		18	2.78

The magnitude distributions are listed in Table II. Because of the bright aurora on Aug. 11/12 this night has been separated from the others. The effect of the aurora on the observations may be seen in the brighter mean magnitudes for this night.

It is a pleasure to note this observing activity and thanks are due to all those who assisted in these programmes. Thanks are also due to Miss J. D. B. Stewart for assistance in preparing the material for publication.

Fredericton Observations of the Orionids and Geminids, 1953

Under the direction of Prof. J. E. Kennedy observations of the Orionid and Geminid showers were carried out at the University of New Brunswick in 1953. It is interesting to recall that this is the location of Canada's first astronomical observatory and that the original building, erected in 1851, is still standing.

The one night on which Orionid observations were made was clear, with a quarter moon and some aurora. The weather for the Geminids was very poor and there were brief clear periods on only one night. Those taking part in these observations are listed below:

J. W. Baker, J. E. Kennedy, J. F. King, A. G. Patterson, Miss M. Roach.

The numbers of meteors seen are summarized in Table III. The mean magnitude of the meteors observed in October was very nearly 3.0, the mean magnitude of the December meteors 2.7. With this commencement of observational activity in the Maritimes we will be looking for more in the future.

TABLE III

Summary of Orionid and Geminid Observations, 1953

Date (1953)	Observing Period (Standard Time)	Average Number of Observers	Total Meteors Observed		Peak Rate Reduced to 6 Observers	
			Shower	Non-Shower	Shower	Non-Shower
Oct. 17/18	2000–0120	2	14	36	15	25
Dec. 8/9	1930–2330	2	8	11	10	10

NOTES AND QUERIES

Donald H. Menzel the New Director of the Harvard Observatory

In September 1952 Harlow Shapley retired as director of the Harvard Observatory, and Donald H. Menzel was made acting director. On Jan. 14, 1954, President Nathon M. Pusey of Harvard announced that Dr. Menzel had been appointed director. He is the sixth director of the Observatory in the 115 years of its existence.

Dr. Menzel is A.B., University of Denver, 1920; Ph.D., Princeton, 1924; hon. A.M., Harvard, 1942. He states that he will carry on a constantly expanding programme, with special emphasis on radio astronomy. There is a new 25-foot radio telescope at the Agassiz station which is making noted progress. Special attention will be given to the border fields of physics, geophysics and aerodynamics, and an effort will be made to have increased co-operation with other observatories and institutions which are interested in these border fields of science.

An expenditure of over $300,000 is to be made in modernizing equipment and a new office building is to be put up at Cambridge, Mass.

The high-altitude observatory at Climax, Col., an upper-air research station in Sunspot, N.M., and two meteor-observation stations near Las Cruces, N.M., will be continued. The Boyden Station in South Africa is to be transferred to other management.

Dr. Menzel is 52. He came to Harvard as an assistant professor in 1932.

C. A. C.

Astronomy from the Artificial Satellite

For some years now, scientists have been more or less seriously considering the construction and operation of a man-made moon, circling the earth at an altitude of slightly more than 1,000 miles in two hours. Assembled from pre-fabricated parts hauled into the orbit by huge, three-stage rockets, this space station would be located in essentially empty space.

Dr. Fred L. Whipple of Harvard, and other astronomers have considered the feasibility of astronomy from such an artificial satellite. Two conditions existent on the satellite would make the telescope design quite different from ones employed here on earth. These would be the absence of our customary gravity and of our customary atmosphere. The observer would not be able to touch the telescope at all because of the

tremendous effects of even the slightest push. The telescope would no longer point at the desired object. It might even start drifting away from the satellite if not tied to it. Hence all guiding, film changing, etc. would have to be remote control. Covering the surface of the mirror with a reflecting coat would be easy because of the complete vacuum in space. Furthermore, much electronic equipment would operate without the complication of vacuum seals, which constitute a considerable problem of electronic design and construction in a gaseous medium like our atmosphere. However, this same atmosphere would no longer shield the telescope (and observer) from the rapid temperature changes which would be produced by both sun and earth. Shields would have to be constructed.

The number of useful astronomical observations which could be made is almost infinite. The entire spectrum would be opened to us on the satellite station, from less than 1A. in wave-length up to radio-type waves comparable to the dimensions of the earth. Extremely large antennae could be conveniently constructed in space so as to increase the resolving power of radio telescopes. The sun could be studied in much detail. The planetary problems would make use of the high resolving power of a large telescope. On Mars, for example, a resolving power of approximately 10 miles would be possible with a 100-inch telescope. Spectra of stars would reveal the minute details of the stellar atmospheres and give more insight into evolutionary problems. The interstellar material would be much more observable. Perhaps the most important problems for the space astronomers would then become new ones, beyond our present day conceptions.

Current issues of the *Journal of the British Interplanetary Society*, available in the Society's Library, should be consulted for more information on this subject.

W. R. H.

Do the Comets Emit Radio-waves?

This problem has been discussed from a theoretical point of view by S. M. Poloskoff in the *Russian Astronomical Journal* (vol. 30, p. 68, 1953). Though such radiation has not yet been observed, the author thinks it should be possible to observe it under favourable conditions.

One may consider the continuous and the monochromatic radiation of comets successively. The intensity of continuous radiation would depend on the density of ions and electrons, and on the absorption coefficient of the gas of comets. Assuming an electron density of the gas in the tail of comets equal 10^3/cu. cm., the expected intensity of radiation in the region of one-metre band is $I = 2.4 \times 10^{-26}$ watt/cm.^{2} grad^2 which is much too weak to be observed with the present radio-tele-

scopes. Only in the case of comets approaching the sun very closely (e.g. the comet 1882 II) one could expect to receive a weak continuous radiation.

On the other hand emission lines corresponding to transitions between low-energy levels of molecules are strong enough to be spotted by a radio telescope. According to Poloskoff the possible wave-lengths are for the molecule OH 85 and 51 cm., for the molecule CH 125 and 39 cm.

In practice, an observer of the radio emission of comets may encounter more disturbing factors such as the radiation from the molecules of the galaxy and the thermal radiation of the molecules of the earth's atmosphere, especially of OH molecules.

G. A. B.

Meteor Trails and Upper Air Winds

From photographs of meteor trails taken with wide-angle, fast Schmidt and Baker-Super-Schmidt telescopes at two or more stations comes the conclusion that high-altitude winds travel as fast as 200 miles an hour at heights of about 50 miles above the earth's surface. According to Dr. Fred L. Whipple of Harvard College Observatory, these winds change rapidly with altitude at heights of 50 to 70 miles, the change being so high that a new explanation of the source of the wind energy must be found.

The meteor trains which show the greatest wind changes are those which travel through the atmosphere at an angle, while much smaller wind changes are observed with roughly horizontal meteor trains. Dr. Whipple suggests that about half of the energy of motion of these high-altitude winds is from large-scale systematic motions and the rest is from eddies which may be two to six miles deep and 30 miles across.

R. J. N.

Publication of Proceedings of Ionosphere Meeting

In August 1952 the International Council of Scientific Unions held a mixed commission on the ionosphere at Canberra, Australia. Membership of this mixed commission include representatives from the International Scientific Radio Union, International Geodetic and Geophysical Union, International Astronomical Union and International Union of Pure and Applied Physics. The Canadian representative was Dr. D. W. R. McKinley, N.R.L., Ottawa, whose name is known to readers of this Journal. The proceedings of this third meeting have now been printed. The book is available from the General Secretariat of U.R.S.I., 42 Rue des Minimes, Brussels, Belgium. The price is $4.00 U.S. funds.

R. J. N.

MEETINGS OF THE SOCIETY

AT TORONTO

Report of the Secretary for the Year 1953

In addition to the regular meetings, the Toronto Centre continued to stress activities designed to introduce astronomy to the public as a fascinating hobby. We arranged, as usual, a series of summer Star Nights on the University of Toronto campus and a telescope display each evening at the Canadian National Exhibition, and also accepted an invitation to stage an inside display at the First Canadian International Hobby Show held at the Coliseum in February. Result of these contacts with the public was the admission of 102 new members during the year, bringing the total paid membership at the year-end to 460.

Although the moon was absent from the evening sky during the period of the Canadian National Exhibition and no planets were visible (except Saturn very low for a short period on three nights) the C.N.E. display was very successful with more than 5,000 visitors looking through the instruments and others inspecting them at times when the sky was cloudy. Four Star Nights were arranged on the University campus during the summer but one had to be cancelled because of rain. Several of the instruments used at these displays were made by members of the Centre's Telescope Makers Group. To this Group also must go much of the credit for the success of the Hobby Show exhibit for, as well as displaying telescopes and presenting demonstrations of telescope-making techniques, they manned the booth constantly during the ten days of the show. The Centre is again grateful to *The Toronto Star* for having taken advertising space which made printing of our four-page "Sky Facts" leaflet possible for distribution at our various outdoor and exhibit events.

The Telescope Makers Group met approximately once each two weeks during the year. Fourteen members completed telescopes and many more started on the construction job. In order to avoid delays and complications experienced in importing mirror blanks and other necessary materials, the Group has made arrangements to import or purchase in bulk and has complete kits ready for sale to members desiring to make telescopes of their own, these at prices much below those advertised by commercial firms.

Eleven regular meetings were held during 1953, the Council met twice, and a special meeting was held on the University campus on Saturday, November 14, to observe the transit of Mercury. The meetings, held in the McLennan Physics Laboratory of the University of Toronto unless otherwise noted, were as follows:

February 10—Andrew McKellar, Ph.D., Dominion Astrophysical Observatory: "Probing the Atmosphere of Supergiant Stars."
February 24—A symposium on "Construction and Use of the Amateur's Reflector."
March 10—Nancy Roman, Ph.D., Yerkes Observatory: "We Get to Know the Milky Way—How Astronomers Learn About our Galaxy."
March 24—W. R. Hossack: "What the Spectrum Means"; a discussion on "What to Do with Your Completed Telescope."

April 7–F. R. Britton, Ph.D., McMaster University: "Understanding Einstein."
April 21–Handbook Talk: "A Preview of the Summer Skies."
May 19, June 16, July 21, August 18–"Star Nights" on U. of T. Campus.
October 13–Members' Night at David Dunlap Observatory, Richmond Hill.
October 27–Ian Halliday, Dominion Observatory: "Palomar Explores the Universe."
November 10–Members' Night. Talk on "Transit of Mercury."
November 14–Open meeting with telescopes on U. of T. Campus to observe transit of Mercury.
November 24–Jean K. McDonald, Ph.D., Dominion Astrophysical Observatory: "How Canada's Electronic Brain is Aiding Astronomy."
December 8–Motion picture programme, followed by Annual Meeting.

FREDERIC L. TROYER, *Secretary.*

November 10, 1953–The meeting was held at the McLennan Laboratory. The chairman was Dr. W. R. Hossack, First Vice-President.

The following were elected to membership in the Society: John A. Long and Michael Shulman. J. B. Oke was transferred to the Toronto Centre from the Ottawa Centre.

On a motion by Mr. Clark, seconded by Mr. Johnson, Mr. F. L. Troyer, Miss R. J. Northcott and Dr. J. F. Heard were appointed to form a nominating committee for the Toronto Centre.

Mr. Sherrick moved that Mr. E. Greenwood be elected as the representative of the Toronto Centre on the National Council. Mr. Lennox seconded the motion. Carried.

The meeting was turned over to the head of the Telescope Makers' Group, Mr. Jesse Ketchum, for a discussion on the observations to be obtained of the transit of Mercury, November 14, 1953. Various suggestions about how to cut down the sun's light and still see Mercury were offered, but it was agreed that probably the safest method of observation was to use a screen on which the image of the sun could be projected. Mr. Johnson and Mr. Frenkel described their arrangements to avoid both injury to the eyes and the eyepieces of the telescopes. The importance of observing the times of contact were discussed and those who planned on making observations were encouraged to make records as accurate as possible. Mr. Collins gave a very interesting description of a transit of Venus he had observed in 1882. Mr. Troyer pointed out an interesting phenomenon to watch for–the black drop. Just after second contact, as the planet moves out across the disk of the sun, it appears to be joined to the edge of the sun by a dark filament. Before long, the filament appears to break.

With a final reminder of the plans for November 14th, the meeting was adjourned. The members were invited to the new National Headquarters and Library following the meeting.

November 24, 1953–The meeting was held in the McLennan Laboratory. The Second Vice-President, Mr. L. H. Clark, was chairman.

The following were elected to membership in the Society: Warren B. Edmunds; Ugis G. Lama; Henry F. Leslie; David C. M. McKay; Donald A. MacRae; Danny R. H. McManus.

The report of the Nominating committee was presented by Mr. F. L. Troyer.

On request of the Telescope Makers' Group it was further recommended that Mr. Jesse Ketchum be appointed Director of the Group, to succeed Mr. L. H. Clark who has asked to be relieved of this duty.

The speaker, Dr. Jean K. McDonald of the Dominion Astrophysical Observatory and at present working with the electronic computer at the University of Toronto, was introduced by Dr. Helen S. Hogg. The title of Dr. McDonald's address was "How Canada's Electronic Brain is Aiding Astronomy."

Dr. McDonald began her lecture by paying tribute to the late Mr. C. G. Wates of Edmonton, an amateur astronomer and active member in the Society, whose enthusiasm was one of the greatest influences on Dr. McDonald's choice of career.

After a brief description of the history of computing machines, including the work of such outstanding people as Pascal and Babbage, the first winner of the Royal Astronomical Gold medal, awarded for his work on the difference engine, Dr. McDonald went on to discuss the electronic computer at the University of Toronto, the Ferut. This name is derived from the manufacturer, Ferrante, and the University of Toronto.

The mathematical basis of this computer is the binary system of numbers, that is, using only 0 and 1 in place of the numbers from 0 to 9. The relation between these two systems was explained as well as the characters used to represent them. Dr. McDonald passed around pieces of the tape used to feed information to the computer and explained how the operator could keep track of what operations were in progress at any given moment.

After mentioning some of the problems that the Ferut could handle, the problem of building up a model of a stellar atmosphere for an early type star using this computer was discussed. Here one has to worry about the physical parameters temperature, surface gravity and the absorption coefficient, all of which are interdependent. With desk computers it is necessary to make some assumptions in order to simplify and reduce the necessary equations. But with the Ferut, these assumptions can be removed and the computer handles with ease the solution of the thirty-nine equations in thirty-nine unknowns.

Dr. McDonald closed her lecture with a few words stressing the need to remember that the machine does not think for itself. At each point along the way there must be a mathematician instructing the machine, and working out in advance all the possible things that may go wrong.

Miss R. J. Northcott expressed the appreciation of the Centre for Dr. McDonald's very interesting and informative lecture.

Dr. Heard spoke briefly on the financial situation of the Society. He pointed out that the expenditures exceed the income by nearly $1000.00 each year. The National Council had decided that as long as it was at all possible the fees should remain as they are, $3.00 per year. They suggested that in addition to the ordinary membership, there might be a sustaining membership where an additional $7.00 was paid making a total of $10.00 a year, and that those who could contribute an extra $47.00 would become patrons. These donations would be exempt from income tax. Dr. Heard appealed to those who were able to do so to contribute to the Society to enable them to keep membership from becoming a luxury.

The meeting was then adjourned.

December 8, 1953—The meeting was held at the McLennan Laboratory. The First Vice-President, Dr. W. R. Hossack, was in the chair.

The following people were elected to membership in the Society (all from Toronto unless otherwise stated): Edward M. Dennis, Miss Dorothy Fairweather, Fred W. Kirkpatrick, Bruno Werner. The following were nominated and elected on a motion by Mr. F. L. Troyer, seconded by Mr. L. H. Clark, that By-Law II be suspended: Miss Kathleen M. Asman, Donald Harrison (Waterford), Moody Kalbfleisch, Alex Saunders, Yukio Yano.

The programme consisted of the showing of six films about science. These were "What is Science?", "This is the Moon", "The Moon", "A is for Atom", "Day and Night", "Latitude and Longitude". After each film comments were invited from the members with the thought in mind that the Toronto Centre might be interested in purchasing one of the films.

BARBARA CREEPER, *Recorder.*

AT VICTORIA

February 11, 1953—The meeting was called to order at 8:05 p.m. by the president, Mr. Evans. Three new members were introduced and the secretary made an appeal for prompt payment of dues. After Dr. K. O. Wright had answered a question from the question box with regard to the times of sunset and sunrise, Mr. R. S. Evans reported on the current astronomical phenomena and Mr. P. E. Argyle reported briefly on the determination of the colour temperatures and colour indexes of stars by photographic photometry. At 8:40 p.m. the president introduced Dr. J. D. Keyes of the staff of the Royal Roads Military College. Dr. Keyes spoke about "Nuclear Physics". The development of nuclear physics from the turn of the century to the present was reviewed, and special emphasis was laid on the place of nuclear physics in the production of power for civilian use. Reference was made to the medical use of radioactive isotopes and the cobalt bomb and the use of the geiger counter was demonstrated. An interesting question period followed the lecture. Mr. J. Climenhaga thanked the speaker for his most informative and interesting talk.

March 11, 1953—The meeting was called to order by the president Mr. Evans at 8:05 p.m. After the usual business had been attended to, Mr. Ambrose Tree gave a commentary on the recent French publication "L'Astrologie" by Paul Couderc. Mr. Stocks mentioned the fine appearance of Venus and Jupiter and Mr. Bob Peters reported on the current astronomical phenomena. Dr. Anne Underhill spoke for five minutes explaining the terms used to describe planetary configurations. Next the president introduced our speaker, Mrs. J. R. Noble who is a past president of this Centre. Mrs. Noble spoke on "The Philosophy of Modern Astronomy". Her comprehensive discussion covered a wide range of thought from the early primitive beliefs to the complexities of relativity theory with its ideas of mass and energy exchange and of space curvature. Mr. Bob Peters expressed the very hearty thanks of the meeting to Mrs. Noble for her address.

April 8, 1953—The meeting was called to order by the president at 8:05 p.m. and after some remarks by the secretary *re* payment of dues, Mr. Bob Peters reported on current phenomena. Mr. Norman Rogers gave a brief discussion of the green flash seen at sunrise and sunset, and of telling time by the stars. Then the president introduced Mr. W. G. Milne, seismologist at the Dominion Astrophysical Observatory, who spoke on "Earthquakes on the Pacific Coast". Mr. Milne gave a historical survey of the earthquakes that had occurred on the Pacific Coast from Tacoma to

Alaska since 1850, and went on to describe the various seismograph stations that have been set up along the coast in recent years. There have been few serious earthquakes, the one in June 1946 doing the most damage, although there are many small earthquakes each year. After a question period, Mr. N. Rogers moved a vote of thanks to the speaker and the meeting adjourned.

October 14, 1953—The meeting was called to order at 8:00 p.m. and opening remarks were made by the president, Mr. R. S. Evans, welcoming the members after the summer break. Mr. Evans then gave a short talk on the forthcoming transit of Mercury. The president then introduced Mr. P. E. Argyle of the Dominion Astrophysical Observatory who spoke on "Photoelectric Astronomy". The speaker reviewed the methods employed in astronomical observation mentioning visual, photographic, photoelectric, thermo-electric and radio methods. He then went on to discuss photoelectric methods in detail describing both the theory behind the photoelectric process and its application to astronomy. Mr. Evans expressed the hearty thanks of the meeting to the speaker and the meeting adjourned.

E. R. Gibson, *Recorder.*

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